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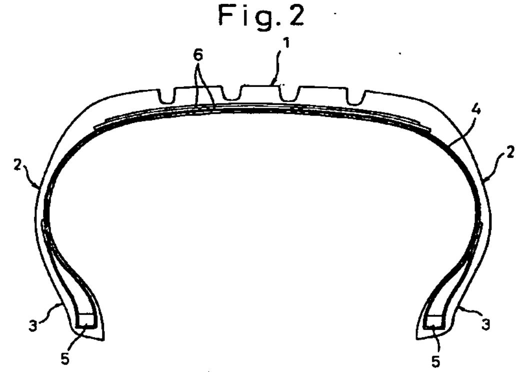
(54) **PNEUMATIC RADIAL TIRE**

(57) A pneumatic radial tire comprising a belt layer, comprised of steel cords having a lateral flat cross-section, arranged around an outer periphery of a tread portion of a carcass layer so that the diameter direction of the steel cords is made to follow the planar direction of the belt layer, the steel cord is made a flat 1 × 6 twist structure comprised of filaments of a filament diameter d of 0.20 to 0.40 mm, the long diameter D_L and twist pitch P of the steel cord taken out from the tire are made with respect to the filament diameter d as follows:

$$3.67\,d - 0.04 \leqq D_L \leqq 3.67\,d + 0.16 \quad 30d \leqq P \leqq 45d$$

and the elongation of the steel cord caused when increasing a load from 0.25 kg to 5.0 kg is made 0.25% or less.

Fig. 2



EP 0 752 325 A1

Description

TECHNICAL FIELD

The present invention relates to a pneumatic radial tire using steel cords in a belt layer thereof, more specifically it relates to a pneumatic radial tire suitable for use in a light truck (LT) or a recreational vehicle (RV).

BACKGROUND ART

In the past, for the belt material of a pneumatic radial tire for a light truck (LT) or a recreational vehicle (RV), steel cords having twist structures of 2+7, 2+6, 3+6, etc. are widely used. These twist structure steel cords, however, become high in cost since two twisting processes are necessary for the twisting and are low in corrosion resistance since there is insufficient penetration of rubber into the steel cord, and therefore, there was the problem of a lower durability of the tire.

To eliminate this defect of the steel cords of requiring two twisting processes, a flattened (or ellipse or oval) open structure of a 1 × 4 or 1 × 5 twist structure has been developed. However, as a result of studies by the present inventors, it has been found that a flattened open structure 1 × 4 or 1 × 5 twist structure is insufficient in strength as a belt material of a pneumatic radial tire for a light truck or a recreational vehicle. Therefore, consideration may be given to making it a 1 × 6 twist structure or a larger number 1 × 7 twist structure, but the inventors found that there was the defect that the cord shape became unstable in the case of a 1 × 7 structure.

However, even when adopting a flattened open structure 1 × 6 twist structure, with the conventional structure as it was, it was necessary to make the flatness ratio (short diameter D_S/Long diameter D_L) smaller in order to ensure that the rubber fully penetrated into the steel cord. Therefore, the long diameter D_L becomes inevitably larger. As a result, when arranging the cord so that its long diameter direction was along the planar direction of the belt layer, when the count of the steel cord is made equivalent to the count of the belt layer used in the past, the interval between cords becomes smaller, and therefore, the problem occurs that the durability of the belt edges falls.

Further, in the case of a 1 × 6 twist structure, there is the problem that the twist structure becomes unstable compared with the 1 × 4 or 1 × 5 twist structure and tends to cause defects in the twisting.

DISCLOSURE OF INVENTION

Accordingly, the object of the present invention is to provide a pneumatic radial tire which, when adopting a cost effective 1 × 6 twist structure for the steel cord of the belt layer, is capable of minimizing the long diameter of the cord to such an extent that the rubber can stably penetrate into the cord, whereby the twist structure is stabilized, and the steering stability and durability of the belt edge portion can be improved.

In accordance with the present invention, there is provided a pneumatic radial tire comprising a belt layer, comprised of steel cords having a lateral flat cross-section, arranged around an outer periphery of a tread portion of the carcass layer so that the diameter direction of the steel cords is made to follow the planar direction of the belt layer, wherein the steel cord is made a flat 1 × 6 twist structure comprised of filaments of a filament diameter d of 0.20 to 0.40 mm, the long diameter D_L and twist pitch P of the steel cord taken out from the tire are made with respect to the filament diameter d, as follows:

$$3.67\,d - 0.04 \leqq D_L \leqq 3.67\,d + 0.16 \quad 30d \leqq P \leqq 45d$$

and the elongation of the steel cords caused when increasing a load from 0.25 kg to 5.0 kg is made 0.25% or less.

BRIEF DESCRIPTION OF DRAWINGS

The present invention will now be explained in further detail with reference to the drawings, wherein:

Figure 1A and Fig. 1B are each a lateral cross-section view of a steel cord used in a belt layer of a pneumatic radial tire of the present invention;

Figure 2 is a cross-sectional view along the meridian of an example of a pneumatic radial tire according to the present invention;

Figure 3 is a graph illustrating the relationship between the long diameter D_L and the filament diameter d of the cord; and

Figure 4 is a cross-sectional view along the meridian of another example of a pneumatic radial tire according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

According to the present invention, as previously mentioned, when the steel cord comprising the belt layer is made a cost-effective 1 × 6 twist structure, the cord long diameter D_L and the twist pitch P in the ranges specified above by the above formulas, the twist structure can be stabilized, while the stable penetration of the rubber into the cord is maintained and further since the cord long diameter is minimized as is necessary, the necessary cord intervals can be maintained even with the same cord count as in the conventional belt layer. As a result, it is possible to keep down the reduction of the durability due to belt edge separation. Further, since the elongation of the steel cord in the low load region is small, it is possible to also improve the steering stability.

In the present invention, more preferably, the flatness ratio (D_S/D_L), expressed by the ratio of the short diameter D_S to the long diameter D_L of the steel cord, in the above twist structure may be made in the range of 0.55 to 0.80 and more preferably 0.58 to 0.75. By using such a flatness ratio, the above action and effect can be improved.

The "flattened open" used herein means the lateral cross-section of the steel cord is flattened and the filaments comprising the steel cord do not contact each other, and therefore, form a clearance at least at one location.

Figure 2 is a cross sectional view along the meridian of a pneumatic radial tire according to the first embodiment of the present invention.

In Fig. 2, 1 is a tread portion, 2 a side portion, 3 a bead portion, and 4 a carcass portion. The carcass portion 4 is reinforced by fiber cord arranged approximately 90° with respect to the tire circumferential direction. The carcass layer extends from the tread portion 1 to the left and right side portions 2, 2, and has the two ends folded back from the inside to the outside of the tire around the left and right bead cores 5, 5. The fiber cord forming the carcass layer 4 include, for example, an organic fiber cord such as a polyester fiber cord, a nylon fiber cord, an aromatic polyamide fiber cord, or a polyvinyl alcohol fiber cord.

On the outer circumference of the tread portion 1 of the carcass layer 4 are arranged two belt layers 6, 6 composed of the steel cord of the construction explained below, so as to extend over one circumference of the tire. This steel cord is arranged at an angle of 15° to 60°, preferably 15° to 30°, with respect to the tire circumferential direction, to give a relationship where the two belt layers 6, 6 cross each other.

Note that, in the illustrated example, there were two belt layers, but the number of the belt layers is not limited to two. It may be three or even four, based upon the required performance.

Figure 1A and Fig. 1B are lateral cross-sectional views of the steel cord 8, cut at any location in the longitudinal direction. The steel cord has a structure of a 1 × 6 structure of six filaments 9 twisted into one in the S- or Z-direction and has a shape crushed into a flat lateral cross-section. Between the mutually adjoining filaments 9, 9 is formed at least one clearance where there is no contact (five locations in the figure). By this, the rubber is made easier to penetrate into the rubber and the steel cord 8 becomes a so-called open structure.

Further, as is clear from a comparison of the two cross-sections of Fig. 1A and Fig. 1B, the arrangement and mutual clearance of the filaments at the lateral cross-section of the steel cord 8 are not the same at the two cross-sections. That is, the arrangement of the filaments 9 along the longitudinal direction of the steel cord 8 changes irregularly. Further, the individual filaments 9 are not straight, but have an irregular wave-form.

The steel cord used in the belt layer of the pneumatic radial tire of the present invention has the above flattened open 1 × 6 twist structure and has a filament diameter d of the filaments comprising the steel cord in the range of 0.20 to 0.40 mm. When the filament diameter d is made smaller than 0.20 mm, the cord strength becomes insufficient. Also, the smaller the filament diameter d, the higher the manufacturing cost. On the other hand, when the filament diameter d is larger than 0.40 mm, the resistance to flexing fatigue of the steel cord falls.

Further, in the present invention, the steel cord is made to have a ratio of the size of the long diameter D_L to the filament diameter d of the filament in the state taken out of the tire in the range of:

$$3.67d - 0.04 \leqq D_L \leqq 3.67d + 0.16$$

That is, in the graph shown in Fig. 3, it is made to have the region shown by the hatching. More preferably, it is made to be in the range of:

$$3.67d - 0.02 \leqq D_L \leqq 3.67d + 0.16$$

The term, "state taken out of the tire" was used herein because the cord deforms due to force received during various processes in the manufacture of a tire and the amount of deformation also changes depending upon the manufacturing conditions, tire size, and tire specifications. Accordingly, in order to ensure that the rubber penetrate the cord, it is necessary to specify the cord diameter in the tire state.

The cord diameter in the state taken out from the tire can be specified as follows: That is, the cord taken out from the tire is embedded in plastic having the rubber attached thereto and cured, the cross-section is then polished and an optical micrometer (for example, the V-12 projector made by Nikon) such as a projector capable of measuring down to

0.001 mm is used for the measurement. The maximum diameter length of the cord was defined as D_2 and the minimum diameter length as D_3.

When the size of the long diameter D_L is less than (3.67d - 0.04), it becomes difficult to make the penetration of the rubber into the steel cord a sufficient amount of 80% or more. Further, when the lower limit of the long diameter D_L is made larger than (3.67d - 0.02), the rate of penetration of rubber can be made 90% or more.

However, when the size of the long diameter D_L is made larger than (3.67d + 0.16), the long diameter becomes excessively large, and therefore, when using the same cord count as that which had been used for the belt layer of the conventional radial tire, the interval between cords would become too narrow and the durability of the belt edge would be decreased.

Further, the flatness ratio (D_S/D_L), expressed as the ratio of the short diameter D_S to the long diameter D_L, should be in the range of 0.55 to 0.80.

Further, the above-mentioned steel cord is made to have a ratio of the twist pitch P to the filament diameter d in the state taken out from the tire of

$$30\,d \leqq P \leqq 45d$$

When the twist pitch P is larger than 45d, then one filament in the 1 × 6 structure will easily fall into the center of the cord and, as a result, a poor shape will be generated due to the poor twisting and the penetration of the rubber will decline. Further, when the twist pitch P is less than 30d, the rate of utilization of the strength of the filaments will be decreased, which would be disadvantageous economically.

In the present invention, the cord diameter of the steel cord is kept as small as possible, and therefore, the long diameter D_L is kept small as well by using as the filament a high strength material having a carbon content of 0.82 to 0.92% and a tensile strength of 320 to 380 kgf/mm^2.

Further, the steel cord taken out from the tire should have an elongation when increasing the load from a state of 0.25 kg to a 5.0 kg of 0.25% or less, more preferably 0.2% or less. If the cord has an elongation at a load of 5.0 kg of more than 0.25%, the initial elongation is large, so therefore the handle response is decreased and the steering stability is decreased.

The steel cord comprised of the above structure can be fabricated by processing six filaments to give them a wave-shape in advance, twisting these by an ordinary twisting machine, and then passing the result through a pinch roller to crush it flat.

Further, in the present invention, as shown in Fig. 4, it is possible to arrange at the outer circumference of the outermost belt layer 6 at least one capply 7 composed of an organic fiber cord with a cord angle with respect to the tire circumferential direction of about 0° so as to cover the entire width of the belt layer. By using this configuration, there is the effect that, under conditions of use or application at a relatively high air pressure such as that of a light truck, the elongation of the steel cord of the present invention at the time of a low load is small and also it is possible to effectively suppress the growth of the outer circumference of the tire due to high air pressure.

The organic fiber cord comprising the capply 7 is not particularly limited, but an organic fiber cord with a low elasticity such as a nylon fiber cord. Use of a cord having a larger elasticity, however, that is, an organic fiber cord with an elasticity of at least 800 kgf/mm^2 and further 800 kgf/mm^2 to 5000 kgf/mm^2 is preferred. As an organic fiber cord with an elasticity of at least 800 kgf/mm^2, for example mention may be made of a polyester fiber cord, aromatic polyamide fiber cord (aramid fiber cord such as para phenylene terephthalamide cord), rayon fiber cord, polybenzobisoxazole fiber cord (PBO), or polyethylene naphthalate fiber cord (PEN).

EXAMPLES

The present invention will now be explained in further detail in accordance with Examples, but the scope of the present invention is of course not limited to these Examples.

Examples 1 to 3 and Comparative Examples 1 to 5

Three types of steel filaments composed of filament diameters d of 0.25 mm, 0.32 mm, and 0.37 mm were used and, as shown in Table 1, the flatness ratio, cord long diameter D_L, twist pitch P, and elongation at a load of 0.25 to 5.0 kg were made different to fabricate eight types of flattened open structure 1 × 6 structure steel cords (Examples 1 to 3 and Comparative Examples 1 to 5). Further, the relationship between the filament diameter d and the cord long diameter D_L of the eight types of steel cords was plotted in Fig. 3. In Fig. 3, the black bullets show the case where the relationship between the filament diameter d and the cord long diameter D_L is in the present invention, while the black triangles show the case where it is out of the scope of the present invention.

These eight types of steel cords were observed as to the state of their twist, whereupon it was found that the cord of Comparative Example 3 had too large a twist pitch, and therefore, suffered from a poor twist state.

Seven types of steel cord, not including the cord of Comparative Example 3, were processed into belt layers of counts shown in Table 1 to fabricate seven types of pneumatic radial tires. These tires were measured as to their steering stability, occurrence of cracks at belt edge portions after driving, and penetration of rubber inside the steel cord, whereupon the results shown in Table 1 were obtained.

From Table 1, it is clear that the long diameter of the cord in Comparative Example 1 was too large and with the count indicated, edge separation (cracking) tended to easily occur. Conversely, it was found, in Comparative Example 2 and Comparative Example 5, the long diameters of the cords were too small, so the rubber penetration was poor.

Note that the measured values are values obtained by the following methods:

(1) Steering Stability

The tire was mounted on an actual car and its superior/inferiority evaluated by an average value of feeling tests conducted by five test drivers.

(2) Presence of Cracks in Belt Edge Portion

A tire was disassembled after actual driving over 60,000 km and the presence of cracks in the belt edge portion was visually examined.

(3) Rubber Penetration

The steel cord was taken out of a new tire. Three filaments each of the cord were pulled apart and the degree of penetration of the rubber inside the cord was visually observed. This was shown by the ratio of the portion, where the rubber had penetrated completely among the filaments to the length observed.

Table 1

	Ex. 1	Ex. 2	Ex. 3	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5
Filament diameter d (mm)	0.25	0.32	0.37	0.32	0.25	0.25	0.25	0.37
Flatness ratio	0.70	0.70	0.66	0.65	0.78	0.70	0.70	0.70
Cord long diameter (mm)	0.92	1.25	1.41	1.35	0.86	0.91	1.00	1.30
Twist pitch (mm)	10	12	16	12	10	12	10	16
0.25 to 5.0 kg load elongation (%)	0.17	0.14	0.12	0.15	0.17	0.17	0.30	0.11
Count (filaments/50 mm)	35	30	25	30	35	35	35	25
State of defects of twist	Good	Good	Good	Good	Good	Poor	Good	Good
Rubber penetration (%)	100	100	100	100	50	-	100	10
Steering stability	Good	Good	Good	Good	Good	-	Poor	Good
Occurrence of cracks	None	None	None	Yes	None	-	None	None

<u>Examples 4 to 6</u>

Steel filaments of a filament diameter d of 0.32 were used to fabricate flattened open 1 × 6 structure steel cords with flatness ratios, cord long diameters D_L, and twist pitches P as shown in Table 2. These steel cords were used to fabricate the four types of belt structure pneumatic radial tires shown in Fig. 4 (Example 2 and Examples 4 to 6). Example 2 is the same as Example 2 in Table 1. The cord count of the belt layer of these tires, the presence of a capply, the cord material of the capply, and the elasticity of the cord material are shown in Table 2. Note that in Table 2, 66N means 66 Nylon, PET means polyethylene terephthalate, and ARAMID means an aromatic polyamide.

These tires were evaluated as to the penetration of rubber (%) in the steel cords of the belt layer, the resistance to edge separation of the belt layer, and the growth in the tire outer circumference along with driving as shown below. The results are shown in Table 2.

Rubber penetration (%)

The steel cord of the belt layer was taken out from a new tire and three of the filaments of the cord each were pulled apart to investigate the degree of penetration of rubber inside the cord. The result was shown by the ratio of the length of the portion where rubber had completely penetrated between the filaments to the length observed.

Resistance to Edge Separation

A tire was disassembled after used for actual driving for 60,000 km. Cases of no occurrence of cracks in the end portion of the belt layer are indicated as "good" and cases with cracks as "poor".

Growth of Outer Circumference of Tire

JIS D-4230 was followed. Tires before and after being subjected to a durability test on an indoor drum at different speeds and loads were measured as to the outer dimensions of the belt layer. These were indicated indexed to Example 2 as 100. The smaller the figure, the smaller the growth of the outer circumference (superior).

Table 2

	Ex. 4	Ex. 5	Ex. 6	Ex. 2
Filament diameter d (mm)	0.32	0.32	0.32	0.32
Flatness ratio	0.70	0.70	0.70	0.70
Cord long diameter (mm)	1.25	1.25	1.25	1.25
Twist pitch (mm)	12	12	12	12
Count (filaments/50 mm)	30	30	30	30
Capply	Yes	Yes	Yes	None
Cord material	PET	ARAMID	66N	
Modulus (kgf/mm^2)	800	3300	400	
Rubber penetration (%)	100	100	100	100
Resistance to separation of belt edge	Good	Good	Good	Good
Growth of outer circumference (index)	30	5	45	100

From Table 2, compared to when not providing the capply (Example 2), when providing it (Examples 4 to 6), the growth of the tire at the outer circumference is smaller. The order is the case of use of an ARAMID of a modulus of 3300 kgf/mm^2 as the cord material of the capply (Example 5) < case of use of PET of a modulus of 800 kgf/mm^2 (Example 4) < case of use of 66N of a modulus of 400 kgf/mm^2 (Example 6).

INDUSTRIAL APPLICABILITY

As explained above, in the pneumatic radial tire of the present invention, when the steel cord material comprising the belt layer a cost-effective 1 × 6 structure is made, the cord long diameter D_L and twist pitch P are made a range specified by the above-identified formulas, and therefore, the twist structure is stabilized, while ensuring stable penetration of the rubber and also the cord long diameter is made small to the minimum necessary extent, so even if the cord count is made equal to that of the conventional belt layer, it is possible to maintain the necessary cord pitch, and therefore, it is possible to suppress the occurrence of belt edge separation. Further, since the elongation of the steel cord in the low load region is made smaller, it is possible to improve the steering stability as well.

LIST OF REFERENCE NUMERALS

1. Tread portion
2. Side portion

3. Bead portion
4. Carcass portion
5. Bead core
6. Belt layer
7. Capply
10. Steel cord
11. Filament

D_L. Long diameter
D_S. Short diameter

Claims

1. A pneumatic radial tire comprising a belt layer, comprised of steel cords having a lateral flat cross-section, arranged around an outer periphery of a tread portion of a carcass layer so that the diameter direction of the steel cords is made to follow the planar direction of the belt layer, wherein

   the steel cord is made a flat 1 × 6 twist structure comprised of filaments of a filament diameter d of 0.20 to 0.40 mm and the long diameter D_L and twist pitch P of the steel cords taken out from the tire are made with respect to the filament diameter d as follows:

   $$3.67\,d - 0.04 \leqq D_L \leqq 3.67\,d + 0.16 \quad 30d \leqq P \leqq 45d$$

   and the elongation of the steel cords caused when increasing a load from 0.25 kg to 5.0 kg is made 0.25% or less.

2. A pneumatic radial tire as claimed in claim 1, wherein the flatness ratio (D_S/D_L), expressed by the ratio of the short diameter D_S of the steel cord to the long diameter D_L thereof, is made 0.55 to 0.80.

3. A pneumatic radial tire as claimed in claim 1 or 2, wherein the content of the carbon in the filaments comprising the steel cord is 0.82 to 0.92% and the tensile strength is 320 to 380 kgf/mm^2.

4. A pneumatic radial tire as claimed in any one of claims 1 to 3, wherein at least one capply comprising an organic fiber cord having a cord angle with respect to the tire circumferential direction of about 0° is arranged on the outer circumference of the belt layer so as to cover the entire width of said belt layer.

5. A pneumatic radial tire as claimed in claim 4, wherein the modulus of said organic fiber cord is at least 800 kgf/mm^2.

6. A pneumatic radial tire as claimed in claim 4, wherein said organic fiber cord is at least one fiber cord selected from the group consisting of a polyester fiber cord, an aromatic polyamide fiber cord, a rayon fiber cord, a polybenzbisoxazole fiber cord, and a polyethylene naphthalate fiber cord.

Fig.1A

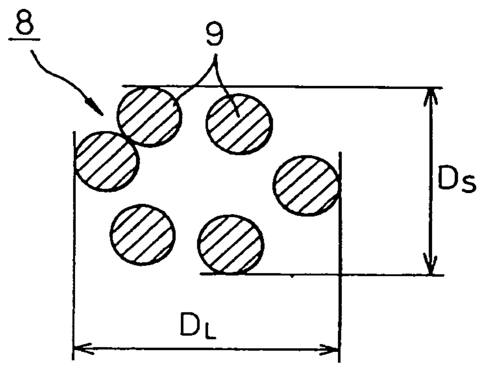


Fig.1B

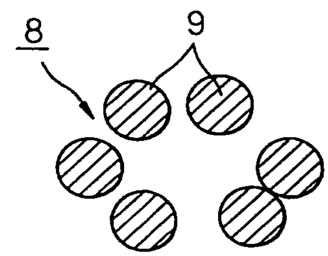


Fig.2

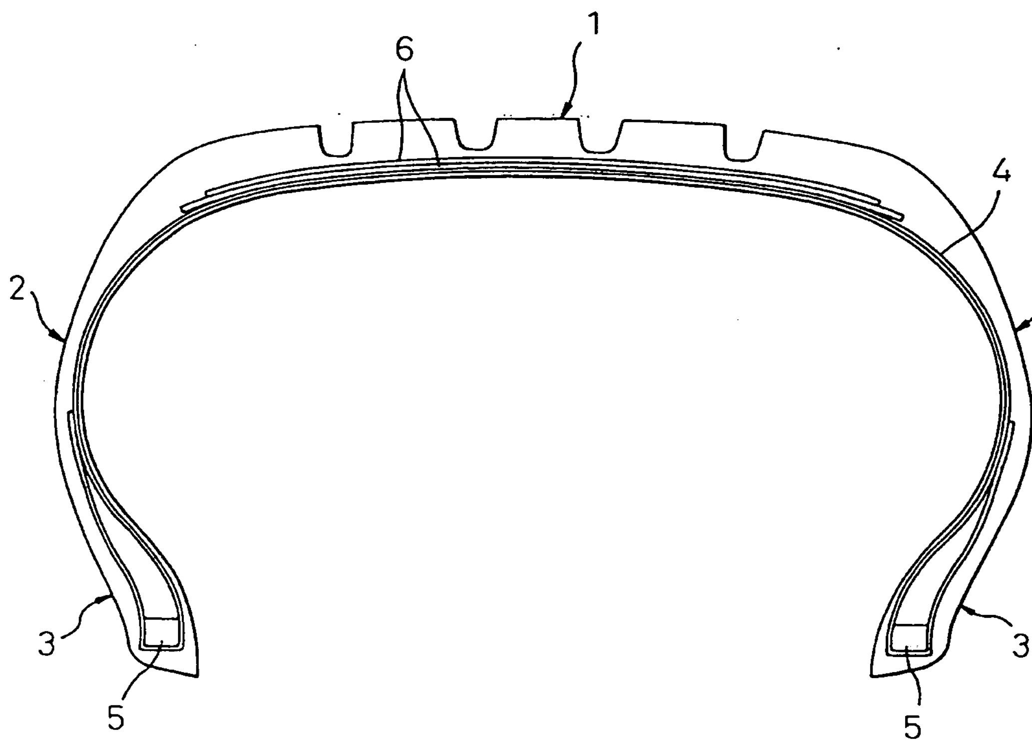


Fig. 3

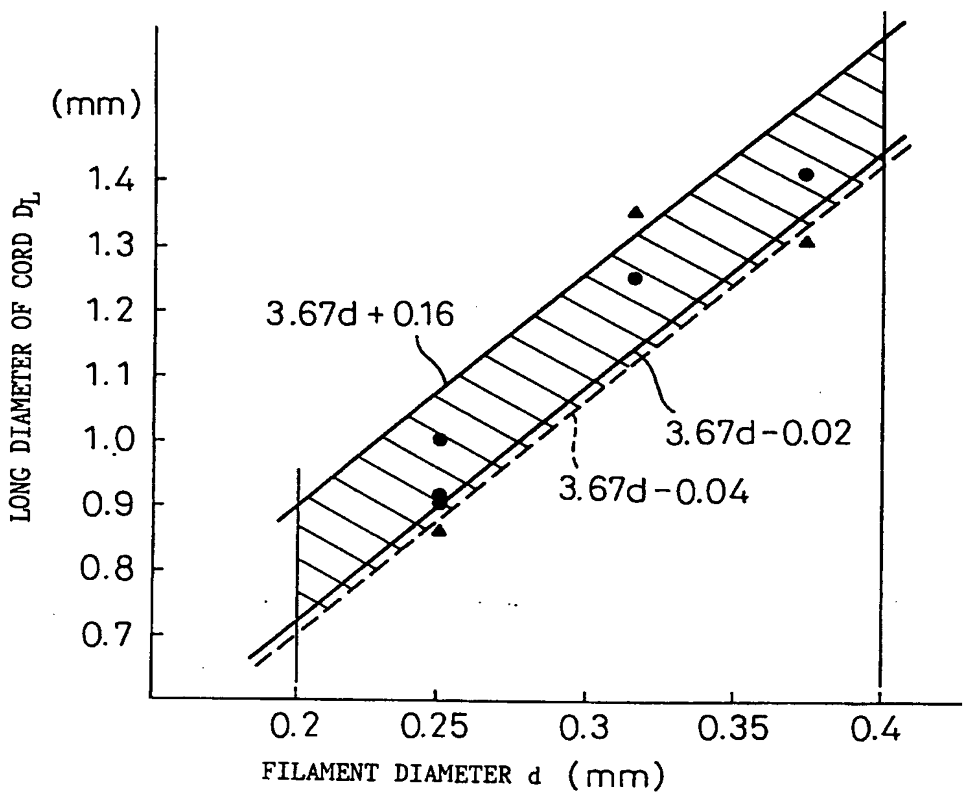
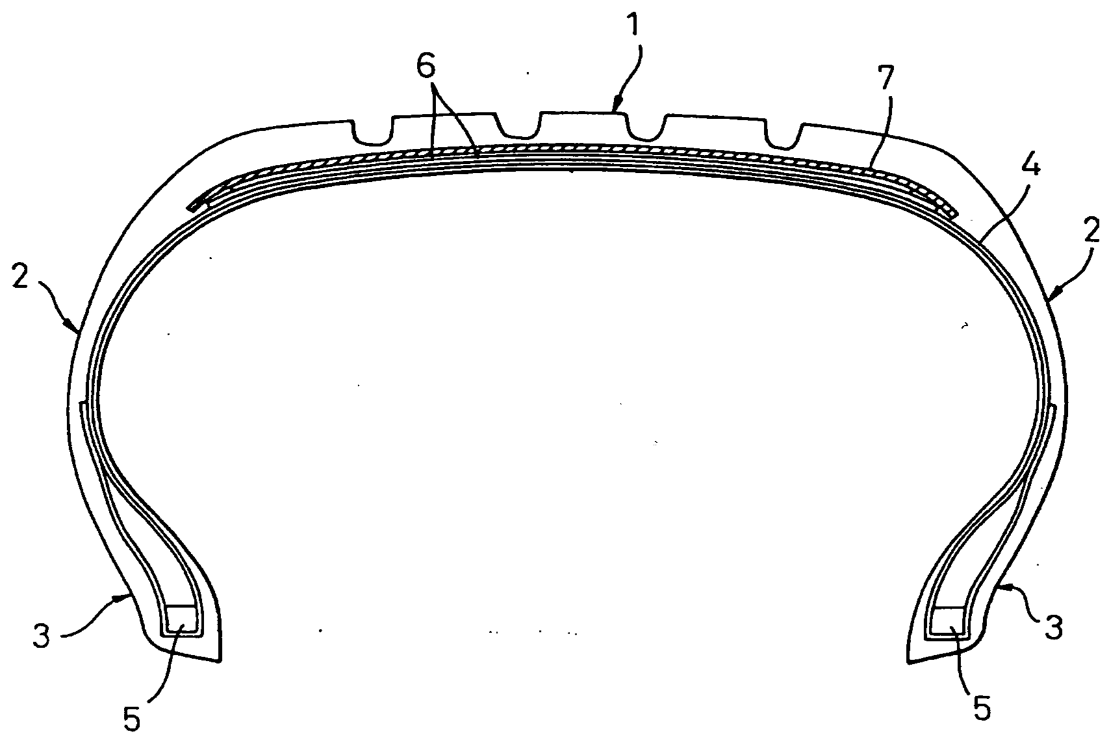

(mm)
LONG DIAMETER OF CORD D_L
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
3.67d + 0.16
3.67d - 0.02
3.67d - 0.04
0.2
0.25
0.3
0.35
0.4
FILAMENT DIAMETER d (mm)

Fig.4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP96/00118

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl6 B60C9/00, B60C9/20, D07B1/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl6 B60C9/00, B60C9/20, D07B1/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926 - 1995
Kokai Jitsuyo Shinan Koho 1971 - 1995

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 4-3474, B (Bridgestone Corp.) January 23, 1992 (23. 01. 92) & US, 4836262, A	1 - 6
Y	JP, 4-77, Y (Tokusen Kogyo K.K.), January 6, 1992 (06. 01. 92)	1 - 6
Y	JP, 1-26882, B (Bridgestone Corp.), May 25, 1989 (25. 05. 89)(Family: none)	1 - 6
Y	JP, 63-270886, A (Bridgestone Corp.), November 8, 1988 (08. 11. 88)(Family: none)	3
Y	JP, 3-96402, A (Sumitomo Rubber Industries, Ltd.), April 22, 1991 (22. 04. 91)(Family: none)	4 - 6
Y	JP, 62-105805, U (Bridgestone Corp.), July 6, 1987 (06. 07. 87)	4 - 6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
April 11, 1996 (11. 04. 96)	April 23, 1996 (23. 04. 96)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)